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Differentiated responsibilities of US citizens in the country's sustainable dietary transition

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E-mail: keiichiro.kanemoto@gmail.com**Keywords:** US dietary environmental footprint, EAT-Lancet diet, planetary health diet, water footprint, land footprint, GHG footprint, sustainable dietary transitionSupplementary material for this article is available [online](#)**Abstract**

If widely adopted, the 'planetary health diet' (PHD), proposed by the EAT-Lancet Commission, would help to meet ambitious sustainability goals currently jeopardised by excessive and resource intensive food demand. To date, convergence of nations to the PHD has been assessed using average food consumption patterns, overlooking the influence of different consumers within this context. Using self-reported dietary intake data from a snapshot survey of the US we reveal the differentiated responsibilities of US citizens within the country's adoption of the PHD otherwise hidden by use of country averaged dietary intake data. We show how such a granular analysis of food consumption patterns is critical to identify levers in the sustainable food transition of nations. By combining 7418 individual food intake reports from a representative cross section of the United States (US) with commodity-level impact data we estimate the overshoot of US dietary patterns in relation to the PHD and their impacts across the climate, water and land system. The net environmental impacts of PHD adoption across the US population are quantified based on realistic dietary shifts. We estimate that US overshoot of the PHD is responsible for 70% of the US dietary greenhouse gas (GHG) footprint. However, over 60% of this burden could be eliminated by just 10% of the US population following the PHD. Although we estimate PHD adoption will more than half the US dietary GHG footprint and land footprint, we find it may have unintended consequences on water demand due to increased tree nut consumption. Across almost all food categories, we show that the food choices of the top tier of consumers in the US create, and must bridge the PHD gap. As such, actions by these consumers will be of major consequences to the speed and direction of the country's sustainable dietary transition. To avoid environmental trade-offs, dietary policies must be scrutinised across multiple sustainability criteria.

1. Introduction

The 'planetary health diet' (PHD), proposed by the EAT-Lancet Commission, offers the first dietary goal-post for meeting nutritional needs and reducing their environmental burden in tandem [1]. A global transition to the PHD, as called for by the Commission, would offer a double dividend, addressing the health risks of malnutrition and curbing the unsustainable toll of food consumption on natural resources, ecosystems and the climate [2]. Yet, the alignment of national food consumption patterns with this

goal remains poorly understood. Using country averaged data, recent studies provide a partial insight, indicating a large gap between current food consumption patterns and the PHD [2–4]. However, large disparities between diets within countries, as shown in recent country case studies [5–7], imply a more complex picture of national convergence to the PHD.

A population wide understanding of food intake patterns is needed to formulate effective and equitable policies for a sustainable dietary transition, but remains peripheral to the study of national

alignment to the PHD. Such a perspective can reveal large inequalities between the contribution of groups, households, and individuals to unsustainable patterns of food consumption, as illustrated by recent green house gas (GHG) footprinting assessments [8–10]. Consequently, exploring not only where, but by how much a country exceeds the PHD can help to better comprehend the scale, scope and nature of policy action required to achieve a sustainable dietary transition. Here we examine the US context, offering the first dietary gap assessment against the PHD using self-selected diets reported from a representative cross-section of the population.

The United States (US) offers an apposite country of assessment against the PHD for several reasons. First, the GHG and resource footprint of the US diet exceeds that of most other high-income nations [2], suggesting a greater potential for environmental impact reduction via the adoption of the PHD. Semba and colleagues [4] show that per capita (GHG) emissions savings associated with a shift of current consumption patterns to the PHD are particularly high within the US, ranking fifth in an analysis of 101 countries. Similarly, Sun and colleagues [11] find the greatest potential for GHG emissions reductions, resulting from shifting agricultural production and carbon sequestration on spared land, linked to US adoption of the PHD, in a study of 54 high income nations. Second, food consumption patterns in the US have been found to be extremely diverse [6,12], highlighting the need to understand the differentiated responsibilities of consumers to the adoption of the PHD. Lastly, according to a survey of 159 countries by Hirvonen and colleagues [13], the PHD is most affordable in the US, suggesting greater feasibility for its wide scale adoption.

Previous sustainability assessments of US diets have been levelled at two scales: (i) gap assessment of average diets against dietary guidelines and (ii) environmental footprint analysis of self-selected diets. Gap assessments have found a large misalignment between the diets of Americans with national and international dietary guidelines for health and sustainability, including the PHD [3–5, 14]. However, such assessments do not capture the true scale of overshoot of such guidelines in relation to actual patterns of food intake, disguising the responsibilities of different consumers within a sustainable dietary transition. In contrast, use of self-selected dietary data captures the diversity of dietary habits and the relative contribution of consumers [6, 15, 16], but not their proximity to dietary guidelines, such as the PHD, neglecting the scale and nature of dietary shifts required across the population to support sustainable patterns of food consumption. Bassi and colleagues [12] offer such an assessment, comparing US dietary intake to the PHD across different socio-demographic groups, but limit assessment to (i) total dietary GHG footprints

of US citizens instead of evaluating their overshoot in relation to individual PHD product guidelines and (ii) climate outcomes from uniform convergence to the PHD among groups as opposed to modelling group-specific dietary shifts.

We attempt to bridge these scales of analysis, offering an assessment of convergence between US diets and the PHD based on self-reported data and realistic dietary shifts, across the climate, water and land system. Using self-reported dietary data, we quantify the distribution of food consumption against the PHD guidelines across each of the main food intake groups (covering whole grains, animal products, fruits, and legumes). Environmental life-cycle data were linked to these intake distributions to quantify the water, land, and GHG footprints of food intake across the population, estimate the environmental burden of overshooting the PHD, and assess the potential environmental outcomes of dietary shifts across the population. Within this study, overshoot refers to the extent of excess consumption, in individual food groups and overall, above the recommendations of the PHD.

2. Methods

This section describes the data and processes involved in (i) converting dietary data to commodity consumption, (ii) linking dietary commodity data to environmental impacts, and (iii) estimating the effects of realistic dietary shifts towards the PHD.

The US National Health and Nutrition Examination Survey (NHANES) [17] underpins the distributional analysis of US diets and their environmental impacts within this study. This survey and data captures self-reported dietary intake from a representative cross-section of the US population and reflects the types and amounts of food and beverages Americans (including adults, children and infants) consume, from a list of 8690 products, during two 24 hour recall periods. Food intake distributions were modelled from these data, averaging across the two day food intake reports, to project total US food intake. We used the latest version of the NHANES survey data (2017–2018) and analysed 7418 individuals' self-reported dietary intake and socio-demographic characteristics (e.g. age, income, household size, race), after filtering 222 records which we assessed were outliers (three times above/below the median value) or incomplete, a procedure employed in other dietary footprinting studies [18–20]. The NHANES survey and data captures self-reported dietary intake in the form of processed foods (e.g. cheese and meat quiche) and whole meals (e.g. burrito with eggs and beans) and not an individual's food commodity demand which is mostly indirect via these forms. A three-step process was used to estimate the food commodity

demand linked to individual's daily food intake and its associated proximity to the PHD range. First, food products and meals within the NHANES dataset were converted to 484 food commodities using food-commodity recipes from the US EPA [21]. Second, the resultant commodity estimates were scaled by raw commodity equivalents to calculate the total input of raw commodities to processed commodities (e.g. tomatoes to tomato puree or wheat grain to flour) using US-specific estimates from Heller and colleagues [6] and FAO [22]. Lastly, commodity-level dietary intake were grouped to 53 commodity groups for assessment of their environmental intensity and overall impact.

The GHG footprints (expressed in CO_{2eq}), land footprints, and water footprints of commodity groups were sourced from Poore and Nemecek's [23] meta-analysis of food system environmental footprinting studies. GHG emissions associated with fish from marine fisheries were sourced from Greer and colleagues [24], based on average CO₂ emissions from fuel combustion in US fisheries fleets in between 1950 and 2016. To more accurately assess the production source and associated environmental impacts of US diets spatially-explicit modelling and life-cycle assessment of US food supply chains is needed [25]. This analysis can accommodate future improvements in the resolution of commodity-level environmental footprints by re-concordance of consumption and impact data. Although not considered within this study, biodiversity impacts of food choices constitute a further impact category of concern within the context of US food choice [26].

Physical and environmental overshoot assessment of US diets to the PHD was achieved by linkage of consumption and impact data generated by the aforementioned steps to 19 of the PHD food categories. The distribution, overshoot and impacts of consumption in each of the 19 PHD food categories were calculated by first aggregating consumption across the 53 commodity groups and then using a weighted environmental intensity factor to assess their impact which reflected the relative share of commodity consumption in each category. The scale and impacts of dietary shifts require to align US food consumption with the PHD guidelines were calculated such that (i) intake below the minimum PHD level would increase to this level, except in the case of animal products which are considered non-essential; (ii) intake above the median PHD level would decrease to this level; and (iii) intake above the maximum PHD level would decrease to this level. In all cases, a minimum nutritional requirement, within the bounds of the PHD guidelines, is satisfied. Data from these scenarios and their distributional effects on the US dietary GHG footprints, land footprints and water footprints can be found in the Supplementary Material.

3. Results

We estimate that over half of all US food consumption is found to exceed the PHD guideline intake recommendations, based on self-reported dietary intake data. Overall, this corresponds to 70.3% of the dietary GHG footprint of the US, 73.5% of its land footprint, and 63.1% of its water footprint. However, the scale and environmental burden of PHD overshoot vary widely between food categories, as summarised in table 1 and shown in full in the Supplementary Material for 19 food categories and 53 food commodities analysed.

The greatest overshoot of the PHD is observed for US beef and lamb consumption (90% of total consumption) which are responsible for the largest GHG footprint and land footprint of the 19 food categories and 53 food commodities analysed (see Supplementary Material). Over two-thirds of pork, dish, chicken, and fruit consumption is also estimated to exceed the PHD guidelines intake recommendations with pork and chicken responsible for similar GHG emissions overall, but pork accounting for the larger share (27.5%) of the US dietary water footprint. Although we find a similar overshoot of the PHD for dairy foods (59%) and starchy vegetables (58%) the former has a far greater toll on the US dietary GHG footprint (by a factor of 71), land footprint (by a factor of 33) and water footprint (by a factor of 475). The apparent gap between the PHD and current dietary trends does not appear to be driven by average consumers in the US, as revealed by the share of the US population responsible for PHD overshoot in table 1. Across almost all food categories, we show that the diets of the top tier of food consumers in the US create, and must bridge, the PHD gap. Figure 1 illustrates how this responsibility is distributed across the US population.

The top 10% of food consumers are responsible for over one-third of the total US dietary GHG footprint and around 60% of the GHG footprint linked to US food intake exceeding the PHD. Almost all (>95%) of the GHG footprint of food consumption in excess of the PHD is driven by top one-third of consumers who also account for two-thirds of the US dietary GHG footprint. Although a more even distribution is seen in relation to overall food consumption, as shown in the Supplementary Material—figure 1, the concentration of beef, lamb, pork, and chicken consumption (70%–75%) within the top 10% of food consumers explains their large contribution to the GHG footprint of US diets and PHD overshoot (as detailed in the Supplementary Material). Dairy foods were the only major food category in which a large share (>50%) of US consumers are found to exceed the PHD guideline intake recommendations.

Mapping US dietary distributions in each of the PHD categories allowed us to quantify the

Table 1. Environmental burden and PHD overshoot of US diets.

Selected food categories	Greenhouse gas	Land	Water	Overshoot of PHD	
	footprint (MTCO ₂ eq)	footprint (Mha)	footprint (Gm ³)	% of total cons.	% of US pop.
Beef and lamb	173.0	48.9	2.1	90%	31%
Pork	77.6	9.9	13.3	84%	30%
Fish	7.6	0.1	0.6	76%	9%
Fruit	23.2	3.7	3.2	71%	38%
Chicken and other poultry	74.8	11.0	3.7	68%	18%
Dairy foods	127.8	10.1	9.5	59%	51%
Tubers and starchy veg.	1.8	0.3	0.02	58%	22%
Eggs	16.1	2.2	2.4	54%	16%
Whole grains	29.3	4.8	6.3	36%	21%
			Average	55%	20%

contributions of different consumers, within a sample of over 7000 individuals, to wide scale adoption of and sustainability gains from the PHD. We quantify realistic dietary shifts required by US food consumers to achieve alignment with the PHD by assessing the proximity of current US dietary intake to the PHD recommended range in each food category based on the tripartite rule explained in the methods. We find that dietary shifts among the top 20% of food consumers contribute 94% to the GHG footprint reduction of PHD adoption, as shown in figure 2.

Despite occupying 60% of the population, Americans representing the broad middle 20%–80% of food consumers contribute just 5.8% to the GHG footprint reduction from PHD adoption. Whilst, encouragingly, a net increase in the dietary footprint GHG of the bottom 20% of food consumers required to meet the PHD's minimum guidelines are small (8.7% of the US dietary GHG footprint). We conclude, population wide alignment to the PHD might more than half the US dietary GHG footprint, a saving equivalent to over 5% of the total domestic GHG emissions of the US in 2017–18 [27]. Notwithstanding that a proportion of these savings will also arise in other countries where the US imports food products, they correspond to more than double the annual GHG emissions reductions achieved within the country over the past decade [27]. At a product level, we find most of these savings will arise from a reduction in red meat (beef and lamb) consumption (67.7%) and consumption of dairy foods (24.1%). We estimate PHD adoption might also produce a large reduction (of 37.4%) in the US dietary land footprint, as shown in figure 3. However, such a dietary shift could also increase the US' dietary water footprint, as shown in figure 4, by around 50%, due to higher tree nut consumption, a trade-off of the PHD also highlighted by Vanham and colleagues [28] and which is a critical concern within the US context [25].

In addition to dietary shifts, reducing food overconsumption offers a further strategy to achieve a sustainable dietary transition. Yet, both measures offer different paths to food system reform, from

incremental to systemic change. Moreover, the potential environmental benefits of these two measures are seldom compared using detailed national dietary intake data. For completeness, we provide such a comparison. To calculate the level of food overconsumption across the population, we compare calorie intake data from survey participants with recommended calorie intake reference values from the USDA [29], adjusted for age and gender. In the absence of participants' exercise habits in the NHANES dietary intake survey analysed within this study, we base recommended calorie intake levels on individuals having a moderately active lifestyle. Infants below two are ignored due to the lack of calorie intake guidelines and consumption habits within this cohort. The resultant analysis, summarised in figure 5, allows comparison between the potential reduction in GHG, water and land footprints of US diets, following (i) adoption of the PHD among the top 20% of US food consumers and (ii) food consumption reduction to meet recommended calorie intake in which overall dietary composition is maintained. We find that reduction in food overconsumption alone has the potential to reduce the GHG footprint, land footprint and water footprint of US diets by 7.7%, 8.1% and 9% respectively. By comparison, adoption of the PHD among the top 20% of consumers may yield a six-fold greater reduction in the dietary GHG and land footprint and two-fold reduction in water footprint of US diets when compared with a strategy of calorie reduction alone. Hence, changes to the composition of diets play a greater role in a US sustainable dietary transition than reducing overall consumption levels whilst maintaining current dietary habits.

3.1. Socio-demographic profiles of US dietary footprints

Using self-reported dietary intake data enables socio-demographic profiling of US dietary patterns and their associated environmental footprints. Such information, provided in the Supplementary Material, can help to distinguish groups with markedly

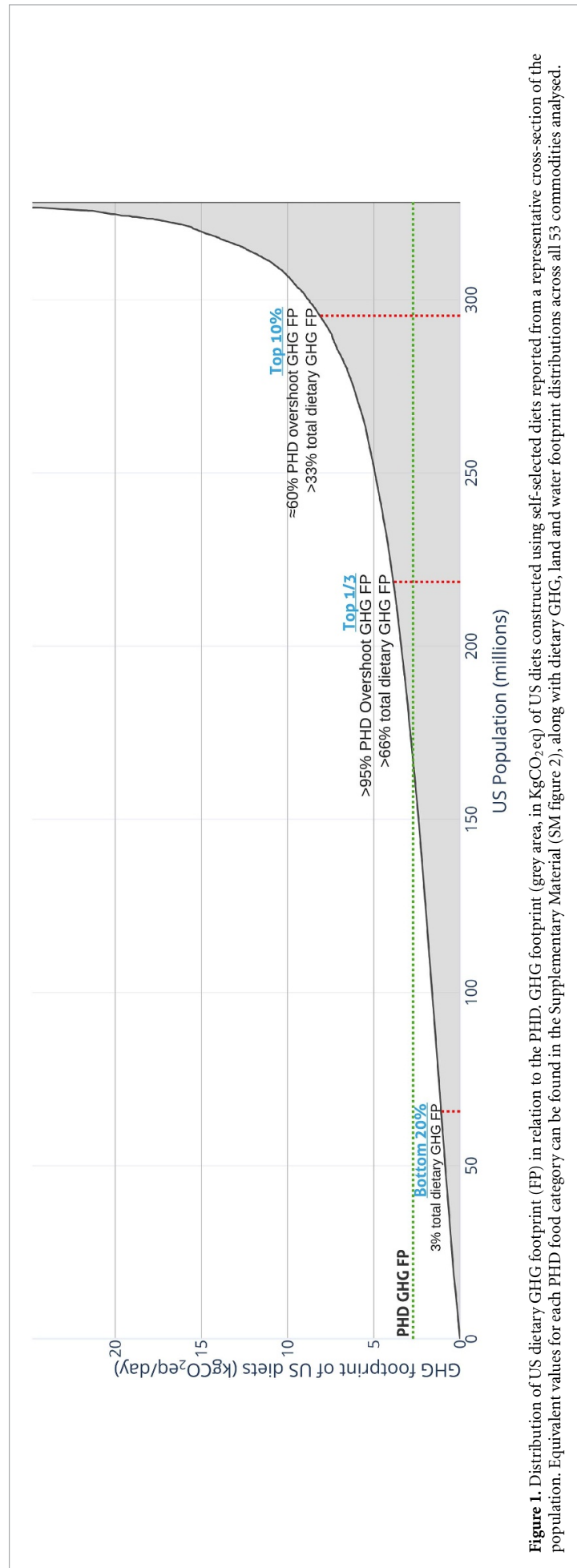


Figure 1. Distribution of US dietary GHG footprint (FP) in relation to the PHD. GHG footprint (grey area, in KgCO₂eq) of US diets constructed using self-selected diets reported from a representative cross-section of the population. Equivalent values for each PHD food category can be found in the Supplementary Material (SM figure 2), along with dietary GHG, land and water footprint distributions across all 53 commodities analysed.

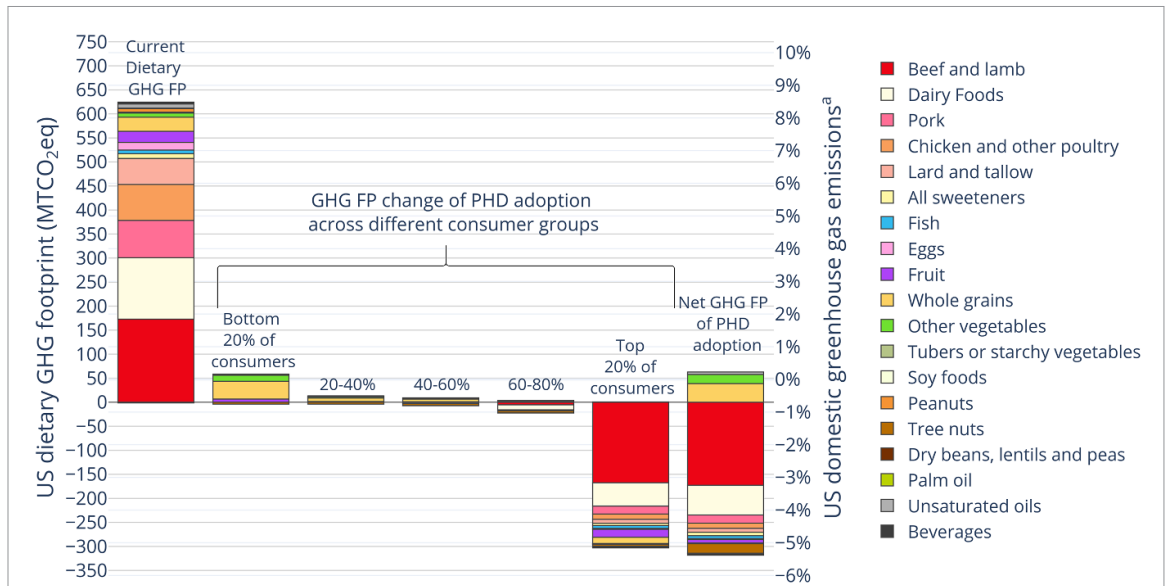


Figure 2. Net GHG (FP) of PHD adoption by consumption quintile. Profile of GHG footprint (in MTCO₂eq) associated with current US diets and their estimated change, by consumption quintile, from national alignment with the PHD. ^aChanges are contextualised in relation to domestic GHG emissions of the US between 2017 and 2018, as reported by the US EPA [27]. Underlying data for US dietary land and water dietary footprints can be found in the Supplementary Material.

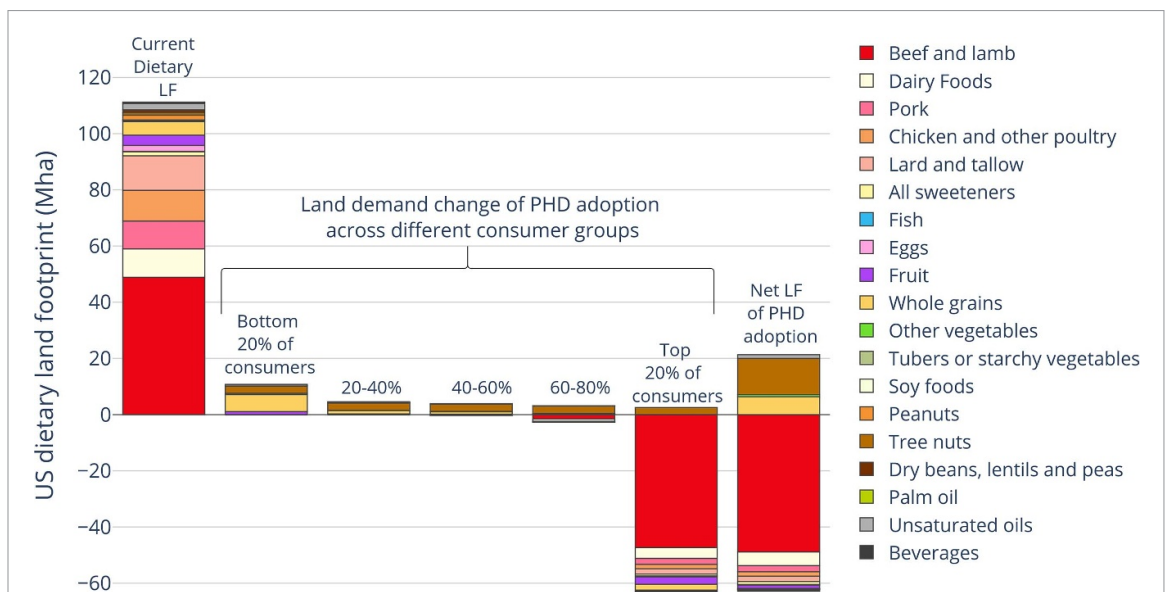
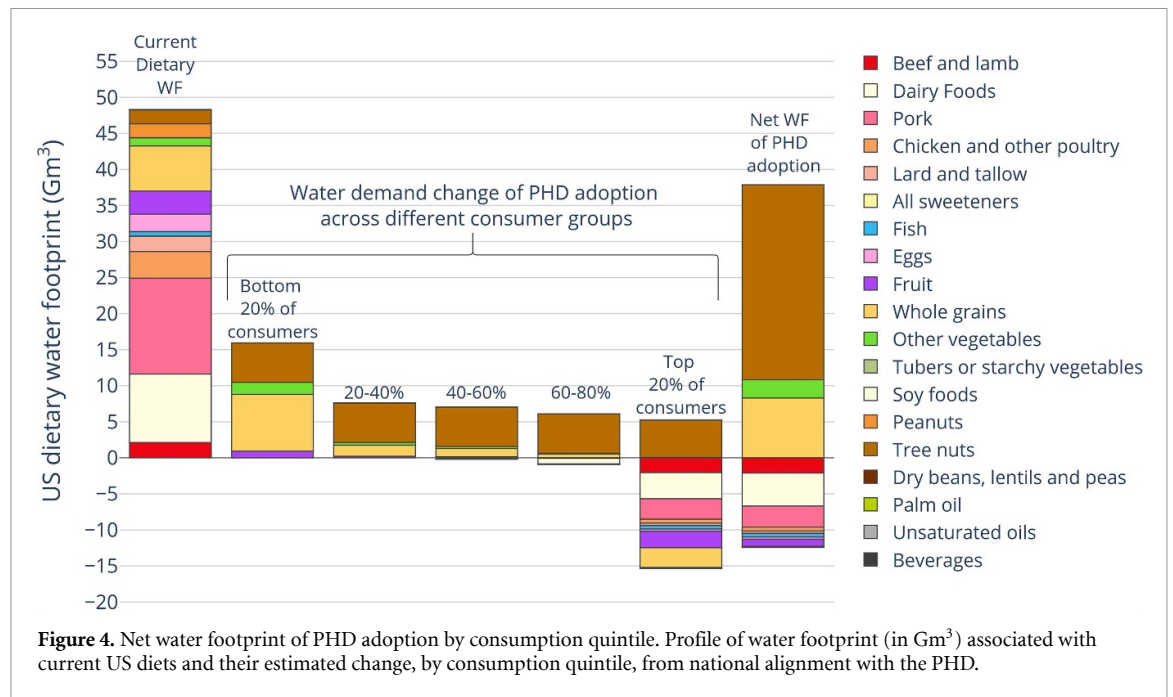


Figure 3. Net land footprint of PHD adoption by consumption quintile. Profile of land footprint (in Mha) associated with current US diets and their estimated change, by consumption quintile, from national alignment with the PHD.

higher dietary environmental footprints, where decisions concerning food choice bear major consequence for the country’s sustainable dietary transition and invites targeted policy support. By integrating dietary intake data and environmental impact assessment with socio-demographic data of participants, we find a large variety in the consumption habits and impacts of different groups. Overall, men possess a marginally (4%) higher dietary footprint (2596kgCO₂eq yr⁻¹) than women (2496kgCO₂eq yr⁻¹). Participant gender does not reflect gender identity or non-binary classification since these are not provided within the NHANES survey. Although no discernible relationship is observed

between age and dietary environmental footprint, a large (as much as two-fold) difference is found between the dietary GHG footprint of different age groups. Marked differences are also found in the dietary patterns and environmental footprints between other socio-demographic groups. Participants who served active duty in US Armed Forces have an 18% higher dietary GHG footprint compared with the general public. Individuals with an educational attainment of 9–11th grade had the highest dietary GHG footprint (2670kgCO₂eq yr⁻¹), marginally higher than college graduates (2592kgCO₂eq yr⁻¹). Whilst a large variation ($\sigma = 104\text{kgCO}_2\text{eq yr}^{-1}$) in dietary environmental footprints are observed



between participants of different marital status. Married individuals had the largest GHG footprint ($2626\text{kgCO}_2\text{eq yr}^{-1}$).

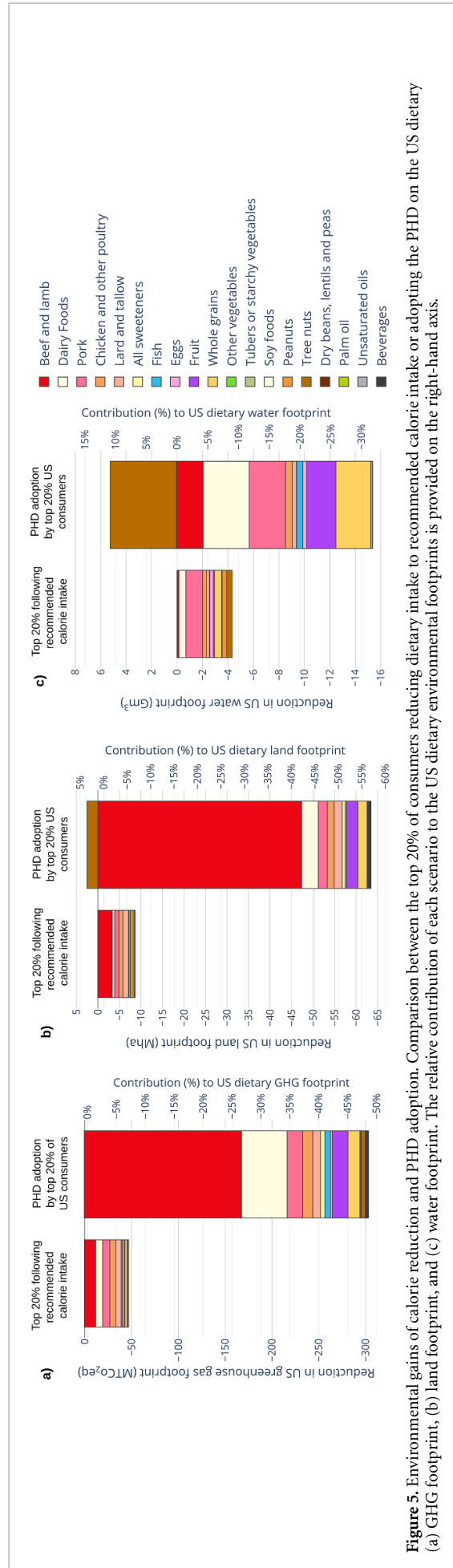
Figure 6 illustrates three noteworthy findings of this socio-demographic analysis, showing the relationship between (figure 6(a)) wealth, (figure 6(b)) household size, and (figure 6(c)) race. As measured by the ratio of personal income to the US poverty threshold, more wealthy individuals tend to have larger environmental footprints (figure 6(a)). Although moderately lower dietary environmental footprints are observed among those with very high wealth, the GHG footprint of non-food consumption in this cohort tends to be disproportionately larger than the rest of the population [30–32]. Dietary environmental footprints also vary by household size. Individuals in households of two people have the lowest dietary GHG footprint. Whilst households of four and above appear to have the highest per capita dietary GHG footprint. This might imply the need to better target larger households as part of a strategy to shift food consumption patterns. We also observe differences in dietary GHG footprints between different ethnic groups (figure 6(c)). Mexican and other Hispanic Americans have the lowest dietary GHG footprint of the six racial groups classified in the NHANES survey. The non-Hispanic white population has the largest GHG footprint. Whilst, the non-Hispanic black population has an above average dietary GHG footprint. Yet, faced with acute economic and structural inequality [33], dietary patterns within this cohort are more likely a symptom of food poverty than choice [16]. Indeed, among the NHANES survey analysed within this study, the non-Hispanic black population has a median income to poverty ratio of 1.63, below the population median (1.94) and the

non-Hispanic white population median (2.1). This profiling can help to guide targeting of interventions whilst also ensuring sensitivity to the economic and socio-cultural challenges facing different groups' adoption of dietary change. Nevertheless, further data collection and analysis is needed to understand fully the complex web of interactions between socio-demographic characteristics and dietary environmental footprints.

4. Discussion

This study reveals the differentiated responsibilities and impacts of US citizens within the country's sustainable dietary transition, otherwise hidden by use of country averaged dietary intake data. We show that targeting food consumers at the top is optimal to achieve the aggressive GHG emissions and land use reductions promised by the PHD. Moreover, these findings suggest that shifting towards a mostly plant-based diet, as prescribed by the PHD, is a far more effective strategy to offset the environmental burden of high food consumption individuals than eliminating their overconsumption of calories (as shown in figure 5). These findings highlight the need for structural changes to US food consumption patterns in order to reduce the environmental burden of the country's food system. Yet, a mix of policy interventions is needed to escape the current lock-in of US citizens to excessive and resource intensive food demand.

The limited application of dietary policy interventions to date renders the design of measures to encourage adoption of the PHD highly unpredictable [34]. Lang and Mason [35] outline different levels of sustainable dietary policy, ranging



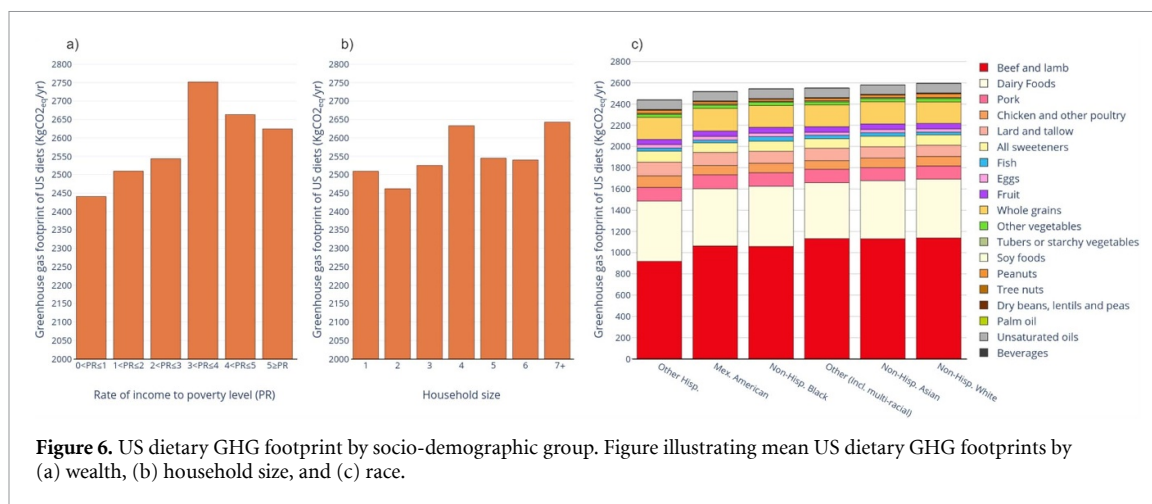


Figure 6. US dietary GHG footprint by socio-demographic group. Figure illustrating mean US dietary GHG footprints by (a) wealth, (b) household size, and (c) race.

from hard to soft measures. Hard policy measures involve guiding, restricting and ultimately eliminating choice of unsustainable food products, through (dis)incentives (e.g. meat tax, food subsidy, or regulating choice) as well as removing high-impact products on a considerable scale. Consumer councils, organised within a participatory economy, tasked with organising and allocating consumption activities, offer a bottom-up strategy to this end [36]. Soft policy measures, characteristic of the prevailing strategy of governments and non-governmental organisations, can involve non-intervention, monitoring food consumption, and enabling sustainable choices via behavioural nudges (e.g. education, branding appeals, and product labelling). Between these extremes lies a process of guiding behaviour change, through restructuring physical micro-environments, such as repositioning meat products to be less conspicuous at the point of purchase (e.g. on food menus or in cafeterias), to reduce demand for high-impact food products [37]. Within a soft policy approach to a sustainable dietary transition, the responsibility for unsustainable food choice tends to fall on individuals, ignoring the perverse incentives, barriers and power structures which shape food consumption patterns. This is symptomatic of the broader attribution of systemic sustainability problems to individuals in order to delay and shift responsibility for environmental action [38]. Hence, the responsibility of governments and markets in promoting (un)sustainable food consumption decisions must be a central focus of a sustainable dietary transition. No one actor or policy measure will overcome the impasse that surrounds the availability of and demand for sustainable food products [35]. However, the sustainability of food systems relies on overcoming such a collective action problem [39].

Detailed socio-demographic profiling of dietary habits is needed to identify and target the groups associated with unsustainable dietary patterns in an effective but equitable manner. In section 3.1

we decompose the differences between the dietary environmental footprint of US citizens using socio-demographic data. This abridged analysis reveals those groups with greatest influence over a sustainable dietary transition in the US. Namely, men, middle- to high-wealth individuals, large households and the non-Hispanic white population. Yet, how such individuals differ in their ability to adopt sustainable dietary choices remains poorly understood. An intersectional lens is needed to fully recognise and accommodate the uneven barriers and capacities of dietary change across the US population, taking account of the myriad factors which shape (un)sustainable decisions in relation to food consumption. Spatial information, currently not reported within the NHANES survey, would also help to reveal intra-/inter-regional inequalities in relation to dietary patterns and their environmental impacts within the US. To design, implement and assess policy interventions in an effective way they need to be guided by the different concerns and capacities of affected stakeholders [40]. Specific attention is needed to understand value-driven decisions in relation to food, including intrinsic identity, risk perception, and group dynamics [41]. Consideration of the practical implications of the PHD for national food self-sufficiency, sovereignty and trade also requires further analysis in order to comprehend fully the winners, losers and trade-offs implied by the PHD. Within this context, it is important to recognise that adoption of sustainable diets will not redress the economic growth imperative and uneven concentration of power within the food system and may even legitimise it [42]. Providing a key part to this puzzle, this study reveals that equity is the key to secure a sustainable US food system.

Data availability statement

The data that support the findings of this study are available upon reasonable request from the authors.

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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